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RESEARCH: STRENGTHENING THE FOUNDATION OF THE NUCLEAR INDUSTRY

by

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at the
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Good morning. I am pleased to join you today for this annual conference on nuclear safety research.

A 19th century British theologian, one Benjamin Jowett, once observed, "Research is a mere excuse for idleness; it has never achieved, and will never achieve any results of the slightest value." My thesis is that this observation is demonstrably wrong with respect to research bearing on the NRC's mission. For example, I believe that research sponsored by the NRC and the Department of Energy, as well as by the industry, has served to strengthen safety significantly. In fact, many of the most important activities now underway at the NRC would not have been possible without the knowledge provided by research activities.

By way of example, I intend to examine some of the important contributions of research to the NRC's traditional safety-related activities and then to turn to an area that is very much on the Commission's and public's mind, power plant security, and discuss how research is being harnessed to address the security issues before us.

There are a broad array of examples of the application of research to strengthen the NRC's safety program. I will mention a few illustrations.

As you know, the NRC has embarked on a long-term effort to reexamine the foundations of its regulatory system. Many of our regulations were developed before there was much practical experience with commercial reactors. As a result, in developing its regulatory program, the NRC and its predecessor, the Atomic Energy Commission, generally proceeded very cautiously, relying on conservative engineering judgment, defense-in-depth, and stringent quality control. One of the earliest efforts of the NRC's research programs -- carried over, in fact, from AEC -- was the development and refinement of probabilistic risk assessment techniques. Continued progress in the development of this tool, augmented by insights gained from several thousand reactor-years of experience in the U.S. and overseas, has enabled detailed examination of the contribution of regulatory requirements to plant safety. This technique is now enabling the Commission to strengthen regulatory requirements where necessary and to reduce regulatory requirements where the regulations do not contribute to safety meaningfully. We are thus able to both ensure safety and reduce unnecessary regulatory burden at the same time.

An example of this approach is reflected in the NRC's current consideration of the possible modification of the special treatment requirements for safety-related structures, systems, and components (or "SSCs"). These requirements impose strict quality assurance standards on the design, construction, installation, maintenance, testing, documentation, and reporting concerning SSCs that are deemed to have safety significance. Insights from probabilistic risk assessments show that many SSCs subject to these stringent requirements are, in fact, not important to safety, whereas some SSCs that were deemed not to be safety-related in fact have risk significance. This knowledge provides the foundation for a possible rule change that may enable a relaxation of the requirements for some SSCs, with a countervailing tightening of requirements for others. The change promises both to reduce unnecessary burden and to enhance safety.

The NRC has also conducted research over the past 30 years to enhance the understanding of severe accidents. This research has obvious direct relevance to the NRC's mission of protecting public health and safety and has also served as a vehicle for regulatory change. A good current example of the application of this knowledge is reflected in the changes to the combustible gas rule (10 C.F.R. § 50.44). The NRC recently determined that the hydrogen recombiner systems required by that rule do not serve to reduce risk because, as shown by experimental work and advanced accident simulation, the hydrogen release that could arise from a design-basis loss-of-coolant accident would not lead to early containment failure for large dry PWR containments and inerted BWR containments. As a result, we are proposing to modify our combustible gas rule so as to relax the requirements on hydrogen monitoring and control for these plants.¹ However, this research also shows that plants with ice condenser and Mark III containments may require additional reliable power supplies for hydrogen igniters to cope with station blackout events. In this case, the information provided by research may enable a relaxation of regulatory requirements for most plants, along with possible tightening of requirements for a few plants that have special vulnerability.

Severe accident research in source term modeling has also allowed regulatory change. The use of postulated accidental releases of radioactive materials is deeply embedded in the NRC's regulatory

¹ 67 Fed. Reg. 50374 (2002)

scheme. Siting criteria in 10 CFR Part 100 require consideration of the potential consequences of an accidental fission product release into the containment resulting from a substantial meltdown of the core. For currently licensed plants, this radiological source term was based on experiments performed in the late 1950s, along with conservative assumptions concerning the time of release and the chemical form of the constituents. These assumptions have significantly affected the design of engineered safety features, such as the BWR main steam isolation valve leakage control systems, in-containment filtration systems, and containment isolation valve closure times. They also serve as part of the basis for the determination of the size of emergency planning zones and of the postulated radiation environment that is used for equipment qualification and for the assessment of post-accident control room habitability and sampling systems accessibility.

The NRC began a major research effort in 1981 to obtain a better understanding of the timing, magnitude, and duration of fission product releases. In addition, studies were undertaken of the chemical form of iodine likely to be found in the containment. Based on this work, a revised source term was developed, which has allowed more realistic requirements for containment isolation timing and leak rates, control room filtration, and main steam line isolation. For those plants that apply the revised source term, safety has also been enhanced by requiring the implementation of pH control in the sump to reduce iodine emissions. Industry and NRC are now examining the possibility of applying insights from this work to modify spent fuel cask requirements.

Underlying all of these activities is a fundamental commitment to safety -- the paramount mission of the NRC. In recent years, we have seen a continuing record of improvement that stems in part from insights provided by research beyond those I have already mentioned. Over the past 15 years, the number of significant events (failures of safety systems, unanticipated plant responses, degradation of key systems or components, and operator errors) has declined on a per plant basis by a factor of nearly 100. This record stems, in part, from advances made in understanding through the analysis of operational experience and the development of predictive tools and management strategies. Research in the area of water chemistry has reduced component degradation rates, the risk of failure, and the need for component replacement. Research in non-destructive examination methods and their verification has helped ensure component integrity while minimizing the unnecessary burden of premature replacement. Advances in risk assessment techniques and their application in the maintenance rule have allowed operational flexibility while enhancing safety. In short, with knowledge derived through research programs, our fundamental commitment to safety has been significantly advanced.

Research insights have also provided an essential foundation for a variety of activities in addition to the revision of regulatory requirements. Many have observed that the United States is now enjoying a nuclear renaissance. And again, research provides the foundation that has allowed this renaissance to occur.

The development and subsequent use of more realistic analysis tools has demonstrated that the margins between calculated plant conditions and operational or regulatory safety limits are often far larger than previously assumed. Licensees have used these tools to justify license amendments that serve to improve economic performance, such as by increasing fuel burnups, changing core power distributions, or increasing reactor power, without intruding on required safety margins. The cumulative effect of the resulting changes is quite remarkable. To date, approximately 11,500 MWt -- or an equivalent of over three large nuclear power plants -- have been gained through implementation of power uprates at existing plants. Planned power uprates are expected to result in an additional increase of over 5900 MWt -- equivalent to nearly two large nuclear units -- in the years ahead. Again, this

contribution would not be possible without the advances in analytical modeling that research has allowed.

Just a few years ago, some pundits claimed that, with the arrival of deregulated electricity markets, nuclear power plants would likely be decommissioned prematurely. We find, however, that rather than moving to shut down nuclear plants, the industry has instead embraced the concept of license renewal. License renewal provides a generating company with the option of keeping a plant operating beyond the term of the original 40-year license, provided the plant can operate safely and reliably. We now expect that nearly all currently licensed reactors will seek to renew their licenses. The central question for the NRC is whether safety margins will be maintained during the period of extended operation.

Fortunately, the NRC and the industry have been working on various aging-related issues for many years. As a direct consequence of these research programs, we have the technical bases to approach license renewal in a manner that focuses appropriately on the effects and management of aging, such as effects on electric cable integrity and the radiation embrittlement and fracture behavior of reactor pressure vessel steels. Again, research has provided the foundation that may enable the current nuclear fleet to contribute significantly to U.S. electricity supply well into this century.

If the national energy policy continues to include a nuclear component, however, there must eventually be new construction. Research programs are already underway to enable both the industry and the NRC to generate the required data, analytical tools, and regulatory framework to support the design and licensing review of advanced reactors. Such designs offer the opportunity for improved safety, lower-cost construction, faster construction, more efficient operation, minimization of waste production, and proliferation resistance. Of course, advances have already been made in the area of passive systems for light water reactors, as evidenced by the AP600 design certification. Severe accident research has been used to inform the in-vessel melt retention concepts of some designs, as well as severe accident management strategies. Again, research will provide the foundation on which any future deployment of nuclear technology will be based.

I hope I have made a compelling case to demonstrate that Jowett's skepticism of the value of research is completely unwarranted. Research is the foundation that underlies some of the NRC's and the industry's most important activities.

Let me now turn to an area in which the full force of our research capacity is only now being fully deployed -- the enhancement of security. In order to provide a backdrop to my discussion, however, let me first take a moment to discuss some of the actions the NRC has taken following the terrorist attacks of September 11 and then indicate some of the issues that research will help resolve.

There have been questions in some quarters as to the adequacy of nuclear plant security and of the measures that the NRC has undertaken to improve it. In fact, nuclear plants had very strong security before September 11. As many of you know, each licensee has the responsibility to protect its nuclear power plant, subject to regulatory scrutiny by the NRC. We have traditionally required our licensees to provide high assurance that they can protect their facilities against a so-called "design-basis threat" or DBT. Our licensees typically develop a comprehensive defensive strategy with measures that include a fenced perimeter (usually a double fence topped with razor wire), intrusion-detection devices, multiple barriers to access, heavily armed guards, and protected defensive positions to help prevent intruders from reaching vital equipment.

The aggressive security that existed before September 11 has been significantly augmented over the past year. Following the attacks of September 11, the NRC issued over 30 safeguards and threat advisories to the major licensed facilities, placing them on the highest security level. Security across the nuclear industry was enhanced as a result of these actions, and many of the strengthened security measures are now requirements as a result of subsequently issued NRC orders. The security enhancements include increased security patrols, augmented security forces, additional security posts, increased vehicle standoff distances, and enhanced coordination with the law enforcement and intelligence communities. We have improved communications with licensees concerning the security of their facilities and have improved linkages with other parts of government, such as the intelligence and law enforcement communities, to keep abreast of the threat environment.

In recognition that the threat environment can change rapidly, we have in place a Threat Advisory and Protective Measures System that specifies predefined protective measures for licensees in response to the assessment of the threat condition by the Commission or the Attorney General pursuant to the Homeland Security Advisory System. The system includes a detailed definition of protective measures that are appropriate to a given threat environment. We had the opportunity to exercise this system on the afternoon of September 10, 2002, when the Attorney General announced the threat condition had moved to the Orange or high level and on September 24 when the Nation returned to the Yellow or elevated level.

Of course, inspection of security capability is necessary to provide confidence in the adequacy of protective measures. As a result, the NRC subjects licensees to detailed inspection, including periodic force-on-force exercises, to determine the adequacy of security measures, and to probe for any weaknesses. The Commission has decided that full security performance reviews, including force-on-force exercises, will be carried out at each nuclear power plant on a three-year cycle, instead of the eight-year cycle that had been applied in the past. These reviews have commenced with table-top exercises that for the first time involve a wide array of Federal, State, and local law enforcement and emergency planning officials.

The Commission is now considering the possibility that a terrorist might use a radiological dispersal device and is actively involved in efforts to defend against this threat. Following the attacks of last September, NRC alerted licensees, suppliers, and shippers of the need to enhance security against the theft of radioactive material. The NRC is also conducting a comprehensive evaluation of controls to protect those radioactive materials that constitute the greatest hazard to public health and safety. For example, we are evaluating approaches for "cradle-to-grave" control of radioactive sources that might be used in a radiological dispersal device and are reexamining the import and export licensing for these isotopes. We are also working with the Office of Homeland Security and other agencies to ensure that the Federal Government is prepared to respond to an event involving a radiological dispersal device.

In short, the NRC has taken a wide variety of steps over the past year in response to the threat environment. But there are issues that research must help resolve. Let me give a few examples.

The current DBT does not include an aircraft attack. In the aftermath of September 11, many asked about the consequences if a large airliner, fully loaded with jet fuel, were to crash into a nuclear power plant. We had to say candidly that we were not sure. We know that reactor containments are extremely robust; they typically are constructed of several feet of reinforced concrete with a steel lining. The plants benefit from redundant and diverse safety equipment so that if any active component becomes unavailable, another system will satisfy its function. Operators are trained to respond to unusual events, and carefully designed emergency plans are in place. Nuclear power plants are certainly

far more capable of responding to an aircraft attack than other civilian facilities of the critical infrastructure. Nonetheless, the NRC had never conducted a detailed engineering analysis of the consequences of a deliberate attack by a large airliner. That work is underway now. We are seeking to determine vulnerabilities and to assess possible mitigation measures.

We also are seeking to assess the vulnerabilities of all types of facilities to a wide spectrum of different types of attacks. For example, analyses are underway of spent fuel pools, as well as dry storage and transportation casks. The security of the transportation and storage of spent fuel is of particular concern in today's environment as a result of controversy surrounding the establishment of a possible national disposal facility for spent fuel and high-level waste. In all these cases, our examinations must include the realistic assessment of vulnerabilities and the consideration of ways to mitigate those vulnerabilities.

Research programs performed in the past for other purposes are fundamental to this effort. Advances in risk assessment techniques, best-estimate modeling of system response to accidents, the application of a realistic source term, as well as structural analysis and consequence modeling are all relevant. There is a necessity, however, to apply and adapt tools and knowledge that have been developed for other purposes to address security concerns.

The NRC has initiated other programs to help ensure the safety of the nuclear power industry in the current threat environment. For example, programs are underway to assess the vulnerability of facilities to cyberterrorism, which is of particular concern as the industry is migrating towards digital instrumentation and control systems. These programs will support the implementation of cyber security audits at selected plants and future review and inspection of safety-related digital system applications.

Computer simulation of small arms conflict is also being considered for use by the agency in assessing the robustness of licensees' protective strategies. The benefits of such an approach arise in several ways: from the speed with which the simulations can be run; from the incorporation of human-behavior modeling, such as the effect of fatigue and training on response time and error rate; and from assurance that the laws of physics are obeyed, such as line-of-sight limitations and the consideration of time delays. This approach promises to enable the assessment of the effectiveness of strategies, barriers, and other protective measures more readily than is currently possible using table-top exercises. It is doubtful that those who began modeling human behavior after the TMI accident ever thought their work would be used to fine tune the protective strategy of a plant.

Designers of tomorrow's generation of nuclear power plants will also need to look carefully at the issue of physical security. As I have indicated, today's nuclear plants are extremely robust facilities. But security improvements can be made.

Some initial discussions with nuclear-plant vendors lead me to believe that the industry recognizes the need to consider security as an aspect of plant design. Some advanced concepts involve the construction of the facility partially or entirely underground, which provides greater protection from external attack. Small, modular plants may have reduced footprints, making it easier to protect vital areas. Passive safety systems can make a plant less dependent on external resources, such as off-site power, and may provide an inherent capability for the plant to be maintained in a safe condition for long periods with minimal operator intervention even if support systems are damaged. This provides an increased opportunity for governmental assets to be marshaled for the take-back of an overrun facility before offsite damage results. And there are numerous other steps that might be considered to increase the resistance of essential plant systems, structures, and components to attack, including protected and

hardened safety system trains, bunkered emergency control rooms, and the use of blast- and penetration-resistant “bank vault”-type doors to protect vital plant areas.

It may not be possible to preclude the possibility of an attack or sabotage event at a plant absolutely, but there are many things that can be done to make such an event extremely unlikely and to ensure that the consequences are reduced.

In short, research can and is contributing to the NRC’s efforts to enhance security at nuclear facilities. I suspect, however, that there is even more insight that research could provide. I invite those of you in the audience who are active in research to look over the horizon to consider challenges in the security area for which you could contribute solutions.

Let me close my comments this morning with a cautionary note. To gain the full benefits of research, the knowledge that is gained must be carefully and thoughtfully applied. Our recent experience with the degradation of the reactor pressure vessel head at the Davis-Besse Nuclear Power Station illustrates what can happen when information is not properly integrated. We understood boric acid corrosion of carbon steel. We understood primary water stress corrosion cracking of reactor pressure vessel head penetrations. Unfortunately, we did not fully integrate the two together and appreciate the resulting safety significance. So let me stress the need not only to perform research, but also to internalize its findings. Henri Poincare once wrote, “Science is built upon facts, as a house is built of stones; but an accumulation of facts is no more a science than a heap of stones is a house.” We must ensure that our research efforts result in facts and knowledge that are applied in a manner which strengthens our capacity to ensure safety and security.

Thank you. I would be happy to answer questions.